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NASA-13100 (June 2004)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA

Superseding NASA-13100 (June 2003)

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DIVISION 13 - SPECIAL CONSTRUCTION

SECTION 13100

LIGHTNING PROTECTION SYSTEMS

06/04

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SECTION 13100

LIGHTNING PROTECTION SYSTEMS

06/04

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NOTE: Delete, revise, or add to the text in this section to cover project requirements. Notes are for designer information and will not appear in the final project specification.

This section lightning covers lightning protection, systems and installation.

****

PART 1 GENERAL

1.1 REFERENCES

****

NOTE: The following references should not be manually edited except to add new references. References not used in the text will automatically be deleted from this section of the project specification.

****

The publications listed below form a part of this section to the extent referenced:

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C135.30 (1988) Zinc-Coated Ferrous Ground Rods for Overhead or Underground Line Construction

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA LA 1 (1992; R 1999) Surge Arresters

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2002) National Electrical Code

NFPA 780 (2000) Standard for the Installation of Lightning Protection Systems

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FS A-A-52913 Splice Connectors

FS W-R-550 (Rev A; Notice 1) Rods, Ground (With

Attachments)

UNDERWRITERS LABORATORIES (UL)

UL 467	(2001) UL Standard for Safety Grounding and Bonding Equipment
UL 96	(2000) UL Standard for Safety Lightning Protection Components
UL 96A	(2001; 11th Ed) UL Standard for Safety Installation Requirements for Lightning Protection Systems

1.2 GENERAL REQUIREMENTS

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NOTE: If Section 16003 GENERAL ELECTRICAL PROVISIONS is not included in the project specification, applicable requirements therefrom should be inserted and the following paragraph deleted.

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Section 16003 GENERAL ELECTRICAL PROVISIONS applies to work specified in this section.

1.3 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01330 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control. Include a columnar list of appropriate products and tests beneath each submittal description.

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The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES in sufficient detail to show full compliance with the specification:

SD-01 Preconstruction Submittals

Material, equipment, and fixture lists shall be submitted for the following items including manufacturer's style or catalog numbers, specification and drawing reference numbers, warranty information, and fabrication site information.

Air Terminals
Main and Secondary Conductors
Ground Rods
Clamp-Type Connectors
Lightning Protection Components
Hardware
Accessories

SD-02 Shop Drawings

Fabrication drawings shall be submitted for the following items consisting of fabrication and assembly details to be performed in the factory.

Air Terminals
Main and Secondary Conductors
Ground Rods
Clamp-Type Connectors
Lightning Protection Components
Hardware
Accessories

Installation Drawings shall be submitted for the lightning protection systems in accordance with the paragraph entitled, "Installation," of this section.

SD-03 Product Data

Manufacturer's catalog data shall be submitted for the following items:

Air Terminals
Main and Secondary Conductors
Ground Rods
Clamp-Type Connectors
Lightning Protection Components
Hardware
Accessories

SD-07 Certificates

Certificates shall be submitted in accordance with paragraph entitled, "System Ratings," of this section.

PART 2 PRODUCTS

2.1 MATERIALS

Lightning protection equipment, Accessories, and Hardware shall conform to NFPA 70, NFPA 780, and UL 96.

2.2 DISSIMILAR METALS

No combination of materials shall be used that forms an electrolytic couple of such nature that corrosion is accelerated in the presence of moisture, unless moisture is permanently excluded from the junction of such metals.

Where unusual conditions exist which would cause corrosion of conductors, conductors with protective coatings or oversize conductors shall be used. Where a mechanical hazard is involved, the conductor size shall be increased to compensate for the hazard or the conductors shall be protected by covering them with molding or tubing made of wood or nonmagnetic material. When metallic conduit or tubing is used, the conductor shall be bonded to the conduit.

2.3 AIR TERMINALS

Air terminals shall be in accordance with UL 96 and NFPA 780, except Class II terminals shall be used for Class I and Class II applications.

Air terminal tips on buildings used for manufacturing, processing, handling, or storing explosives, ammunition, or explosive ingredients shall be a minimum of 2 feet 600 millimeter above the ridge parapet, ventilator or perimeter.

Air terminals shall be a minimum of 5 feet 1500 millimeter above the opening on open or hooded vents emitting explosive dusts or vapors under natural or forced draft.

Air terminals shall extend a minimum of 15 feet 4500 millimeter above vent opening on open stacks emitting explosive dusts, gases, or vapor under forced draft.

Air terminals shall be [5/8-inch 16 millimeter aluminum] [1/2-inch 15 millimeter diameter nickel-tipped copper] with length and location as indicated. Air terminals shall be fastened to a bronze or aluminum connector with a male threaded stud on which the female threaded air-terminal shaft shall be mounted

Air terminals shall be not less than 10-inches 250 millimeter high, tapered to a point. Separate points are not required on top of air terminals, but if used, the points shall be of substantial construction and shall be securely attached by screw or slip joints. Air terminals more than [18] [_____]-inches [450] [_____] millimeter high shall be supported by a suitable brace with guide(s) not less than one-half the height of the air terminal.

2.4 MAIN AND SECONDARY CONDUCTORS

****
NOTE: Delete all references to a counterpoise when soil conditions indicate that a counterpoise is not required.
****

Conductors shall be in accordance with NFPA 780 and UL 96 for Class I, Class II, or Class II modified materials as applicable and shall be [copper] [aluminum].

[Weight Mass of copper conductors shall be not less than 187.5 pounds per thousand feet 0.283 kilogram per meter, and the size of any wire of this cable shall be not less than AWG No. 17. Copper tube or solid-section conductors of copper shall weigh not less than 187.5 pounds per thousand feet 0.283 kilogram per meter, and no tube wall shall be less than AWG No. 20. Thickness of any copper ribbon or strip shall be not less than AWG No. 16. Copper conductors used for counterpoise shall be not smaller than AWG No. 1/0.]

[Do not allow aluminum to contact or touch the earth, dissimilar metals, or constructions where rapid deterioration of the metal could result. Precautions shall be observed at connections with dissimilar metals. Aluminum cable conductors shall be electrical conductor-grade aluminum and shall weigh not less than 95 pounds per thousand feet 0.14 kilogram per meter. Size of any wire of the cable shall be not less than AWG No. 14.

Aluminum conductors for bonding and interconnecting metallic bodies to the main cable shall be at least equivalent to strength and cross-sectional area of a AWG No. 4 aluminum wire. Aluminum strip conductors for interconnecting metallic bodies to the main conductor cable, when void of perforations, shall be not less than No. 14 and at least 1/2-inch 15 millimeter wide. When perforated, the strip shall be as much wider as the diameter of the perforations. Aluminum strip for connecting exposed water pipes shall be not less than AWG No. 12 and at least 1-1/2-inches 40 millimeter wide.]

2.5 GROUND RODS

****
NOTE: Type and number of ground rods to be used will be based on local conditions, earth resistively data, and on the size and type of the electrical installation. Copper clad steel rods should be specified for normal conditions. Galvanized coated steel or stainless steel rods should be used where low soil resistivities are encountered and galvanic corrosion may occur between adjacent underground metallic masses and the copper clad rods. Stainless steel rods have a longer life than the zinc coated steel. In high resistively soils, 10-foot 3 meter sectional rods may be used to obtain the required resistance to ground; however where rock is encountered, additional rods, a counterpoise, or ground grid may be necessary. Coordinate and standardize rod selection for individual facilities with other specification sections.
****

[Rods made of [copper-clad] [stainless steel] [solid copper] [copper alloy] [galvanized ferrous metal] shall conform to UL 467 [and FS W-R-550] [and ANSI C135.30].]

[Ground rods shall be not less than [[1/2] [3/4] inch [15] [20] millimeter in diameter] and [20] [_____] feet [6.0] [_____] meter in length. [10 feet][__] [3 meter] [__] exothermic-fusion-welded section rods shall be utilized to make up the length of rod required.]

[Plate electrodes made of [copper] [iron] [steel] shall conform to UL 467 and shall have a minimum thickness of [0.032] [0.25] inch [0.8] [6] millimeter and shall have a minimum surface contact area of [2] [_____] square feet [0.2] [_____] square meter.]

2.6 CLAMP-TYPE CONNECTORS

Clamp connectors for splicing conductors shall conform to UL 96 and FS A-A-52913, Class 2 noninsulated, style and size as required for the installation. Connectors shall be of corrosion-resistant material and shall afford protection against electrolysis.

2.7 LIGHTNING PROTECTION COMPONENTS

Lightning protection components, such as bonding plates, air terminal supports, chimney bands, clips, and fasteners shall conform to UL 96, classes as applicable.

PART 3 EXECUTION

3.1 INSTALLATION

Installation shall conform to NFPA 70, NEMA LA 1, NFPA 780, and UL 96A.

Installation Drawings shall be submitted for the lightning protection systems. Drawings shall indicate overall physical features, dimensions, ratings, service requirements, and weights of equipment.

3.2 INTEGRAL SYSTEM

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NOTE: When conductors and terminals are detailed on the drawings, delete this paragraph and remaining paragraphs in Part 3 Execution, and add a paragraph for required testing.
****

Lightning protection system shall consist of air terminals, roof conductors, down conductors, ground connections, and grounds, electrically interconnected to form the shortest distance to ground without passing through any nonconducting parts of the structure. All conductors on the structures shall be exposed except where conductors are in protective sleeves exposed on the outside walls. Secondary conductors shall interconnect with grounded metallic parts within the building. Interconnections made within side-flash distances shall be at or above the level of the grounded metallic parts.

3.2.1 Air Terminal Design

Air terminal design and support shall be in accordance with UL 96 and NFPA 780. Terminals shall be rigidly connected to, and made electrically continuous with, roof conductors by means of pressure connectors or crimped joints of T-shaped malleable metal and connected to the air terminal by a dowel or threaded fitting. Air terminals at the ends of the structure shall be set not more than 2 feet 600 millimeter from the ends of the ridge or edges and corners of roofs. Spacing of air terminals 2 feet 600 millimeter in height on ridges, parapets, and around the perimeter of buildings with flat roofs shall not exceed 25 feet 7600 millimeter. In specific instances where it is necessary to exceed this spacing, the specified height of air terminals shall be increased not less than 2 inches 50 millimeter for each foot 300 millimeter of increase over 25 feet 7600 millimeter. On large, flat or gently sloping roofs, as defined in NFPA 780, air terminals shall be placed at points of the intersection of imaginary lines dividing the surface into rectangles having sides not exceeding 50 feet 15 meter in length. Air terminals shall be secured against overturning either by attachment to the object to be protected or by means of a substantial tripod or other braces permanently and rigidly attached to the building or structure. Metal projections and metal parts of buildings, smokestacks, and other metal objects that do not contain hazardous materials, need not be provided with air terminals. These metal objects shall be bonded to the lightning conductor through a metal conductor of the same unit weight per length as the main conductor.

[Where metal ventilators are installed, air terminals shall be mounted thereon, where practicable. Any air terminal erected by necessity adjacent to a metal ventilator shall be bonded to the ventilator near the top and bottom.]

Where nonmetallic spires, steeples, or ventilators are present, air terminals shall be mounted thereon or to the side. In addition, where spires or steeples project more than 10 feet 3000 millimeter above the building, the conductor between the air terminal [and metal roof] shall be continued to the nearest down conductor and securely connected thereto.

3.2.2 Roof Conductors

Roof conductors shall be connected directly to the roof or ridge roll. Sharp bends or turns in conductors shall be avoided. Necessary turns shall have a radius of not less than 8 inches 200 millimeter. Conductors shall preserve a downward or horizontal course and shall be rigidly fastened every 3 feet 1200 millimeter along the roof and down the building to ground. Metal ventilators shall be rigidly connected to the roof conductor at three places. All connections shall be electrically continuous. Roof conductors shall be installed along the contours of flat roofs, ridges, parapets, and edges; and where necessary, over flat surfaces, in such a way as to join each air terminal. Roof conductors surrounding tank tops, decks, flat surfaces, and flat roofs shall be connected to form a closed loop.

3.2.3 Down Conductors

Down conductors shall be electrically continuous from air terminals and roof conductors to grounding electrodes. Down conductors shall be installed over extreme outer portions of the building, such as corners, with consideration given to the location of ground connections and air terminals.

Each building or structure shall have not less than two down conductors located as widely separated as practicable, at diagonally opposite corners.

On rectangular structures having gable, hip, or gambrel roofs more than 110 feet 33 meter long, there shall be at least one additional down conductor for each additional 50 feet 15 meter of length or fraction thereof.

On rectangular structures having French, flat, or sawtooth roofs exceeding 300 feet 90 meter in perimeter, there shall be at least one additional down conductor for each 100 feet 33 meter of perimeter or fraction thereof.

On an L- or T-shaped structure, there shall be at least one additional down conductor; on an H-shaped structure, at least two additional down conductors; and on a wing-built structure, at least one additional down conductor for each wing.

On irregularly shaped structures, the total number of down conductors shall be sufficient to make the average distance between them along the perimeter not greater than 100 feet 33 meter.

On structures exceeding 50 feet 15 meter in height, there shall be at least one additional down conductor for each additional 60 feet 18 meter of height or fraction thereof, except that this application will not cause down conductors to be placed about the perimeter of the structure at intervals of less than 50 feet 15 meter.

Additional down conductors shall be installed when necessary to avoid "dead ends" or branch conductors exceeding 16 feet 4.5 meter in length, ending at air terminals.

Down conductors shall be equally and symmetrically spaced about the perimeter of the structure. Down conductors shall be protected where necessary, to prevent mechanical injury to the conductor.

3.2.4 Interconnection of Metallic Parts

Metal doors, windows, and gutters shall be connected directly to the grounds or down conductors using not smaller than AWG No. 6 16 millimeter, copper conductor, or equivalent. Conductors placed where there is probability of unusual wear, mechanical injury, or corrosion shall be of greater electrical capacity than would normally be used, or shall be protected. Ground connection to metal doors and windows shall be by means of mechanical ties under pressure.

3.2.5 Ground Connections

Ground connections comprising continuations of down conductors from the structure to the grounding electrode shall be connected to the down conductor and ground rod in a manner to ensure electrical continuity between the two. All connections shall be of the clamp type. There shall be a ground connection for each down conductor. Metal water pipes and other large underground metallic objects shall be bonded together with all grounding mediums. Ground connections shall be protected from mechanical injury. In making ground connections, advantage shall be taken of all permanently moist places where practicable, although such places shall be avoided if the area is wet with waste water that contains chemical substances, especially those corrosive to metal.

3.2.6 Grounding Electrodes

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NOTE: Delete all references to a counterpoise in applicable paragraphs when soil conditions indicate that a counterpoise is not required.

Ten ohms should be used for installations covered by DARCOM-R 385-100, Safety Manual. Twenty-five ohms is acceptable at most installations.

In locations where existing underground utilities, equipment or structures may be damaged, ground rod installation should be accomplished using the water jetting method.

****

A grounding electrode shall be provided for each down conductor located as shown on the drawings [Sheet No. [_____], Detail No. [_____]]. [Ground rods shall be installed using a water jetting procedure.] Ground rods shall extend into the earth for a distance of not less than 10 feet 3000 millimeter. Ground rods shall be set not less than 2 feet 600 millimeter, nor more than 10 feet 3000 millimeter, from the structure. Complete installation shall have a total resistance to ground of not more than [_____] ohms (if a counterpoise is not used).

Ground rod resistance shall be measured with the ground under test isolated and under normal dry weather conditions, not less than 48 hours after rainfall.

Ground connections below grade shall be painted with a coat of bituminous

mastic.

When two of any three ground rods, driven not less than 10 feet 3000 millimeter into the ground, a minimum of 10 feet 3000 millimeter, apart, and equally spaced around the perimeter, give a combined value exceeding 50 ohms immediately after driving, a counterpoise shall be used. A counterpoise, where required, shall be of AWG No. 1/0 25 millimeter copper cable or equivalent material having suitable resistance to corrosion and shall be installed around the perimeter of the structure in a trench not less than 2 feet 600 millimeter deep at a distance not less than 2 feet 600 millimeter nor more than 10 feet 3000 millimeter from the nearest point of the structure. All connections between ground connectors and grounds or counterpoise, and between counterpoise and grounds shall be electrically continuous. Where so indicated, an alternate method for grounding electrodes in shallow soil shall be provided by digging trenches radically from the building. Lower ends of the down conductors (or their equivalent in the form of metal strips or wires) shall then be buried in the trenches.

3.3 [WOOD-FRAME] [REINFORCED CONCRETE] BUILDINGS

[[Wood-frame buildings with] [wall-bearing masonry] [a tile structure with metallic roof and nonmetallic exterior walls] [Reinforced concrete buildings with metallic roofs] shall conform to the following requirements.

Metal roofs which are in the form of sections insulated from each other shall be made electrically continuous by bonding. Air terminals shall be connected to, and made electrically continuous with, the metal roof as well as the roof conductors and down conductors. Ridge cables and roof conductors shall be bonded to the roof at the upper and lower edges of the roof and at intervals not to exceed 100 feet 30 meter. Down conductors shall be bonded to roof conductors and to the lower edge of the metal roof. Where the metal of the roof is in small sections, the air terminals and down conductors shall have connections made to at least [four] of the sections in accordance with NFPA 780. All connections shall have electrical continuity and have a surface contact area of at least 3 square inches 1900 square millimeter.]

[Wood-frame buildings with metal roof and metal exterior walls shall conform to the following requirements.

Metal roofs and metal walls shall be bonded and made electrically continuous and considered as one unit. Air terminals shall be connected to and made electrically continuous with the metal roof as well as the roof and down conductors. All connections shall have electrical continuity and have a surface contact area of at least 3 square inches 1900 square millimeter.]

3.4 STEEL-FRAME BUILDINGS

Steel framework shall be made electrically continuous by [bolting] [riveting] [exothermically welding] the steel frame. Air terminals shall be connected to the structural steel framework at the ridge. Short runs of conductors shall be used as necessary to join air terminals to the metal framework so that proper placing of air terminals is maintained. Separate down conductors from air terminals to ground connections are not required. Where a water system enters the building, the structural steel framework and the water system shall be connected at the point of entrance by a ground connector. Connections to pipes shall be made by means of ground clamps with lugs. Connections to structural framework shall be made by

means of [nut and bolt] [exothermic welding]. All connections between columns and ground connections shall be made at the bottom of the steel columns. Ground connections to grounds or counterpoise shall be installed from not less than one-half of all the columns distributed equally around the perimeter of the structure. When no water system enters the structure, ground connections shall be installed from all steel columns distributed equally around the perimeter of the structure. Metal doors, windows, gutters, and similar metal installations shall be bonded to the steel work of the building. A grounding electrode shall be provided for each ground connection.

3.5 RAMPS

Lightning protection for covered ramps (connecting passageways) shall conform to the requirements for lightning protection systems for buildings of similar construction contained in this section. A down conductor and a driven ground rod shall be placed at one of the corners where the ramp connects to each building or structure. This down conductor and driven ground rod shall be connected to the counterpoise or nearest ground connection of the building or structure. Where buildings or structures and connecting ramps are clad with metal, the metal of the buildings or structures and metal of the ramp shall be connected in a manner to ensure electrical continuity, in order to avoid a flash-over or spark due to a difference in potential.

3.6 IGLOO-TYPE MAGAZINES

Reinforcing steel in earth-covered reinforced-concrete, igloo-type magazines shall be made electrically continuous. Electrical continuity may be provided by clipping or brazing, unless a specific method is noted on the drawings. Air terminals and roof conductors shall be securely connected to, and made electrically continuous with, the reinforcing steel. One air terminal shall be located on the top of the front wall and one on or adjacent to the ventilator in the rear. Air terminals shall extend vertically at least 2 feet 600 millimeter above the top of the front wall and the highest point on the ventilator. Down conductors and grounding electrodes shall be provided at diagonally opposite corners of the magazine and shall be connected together. Grounding electrodes shall be connected to the horizontal reinforcing rods below the floor line of the wall system. Steel door frames shall be made electrically continuous with the reinforcing steel. Steel doors shall be connected to steel frames by means of a flexible copper strap or cable unless the steel hinges make the door and frame electrically continuous.

3.7 TANKS AND TOWERS

3.7.1 Wooden

Lightning protection system shall consist of air terminals, ridge cables, down conductors, ground connections, and grounds, electrically interconnected to form the shortest distance to ground without passing through any nonconducting parts of the structure. Where the roof of the structure ends in a peak, a single air terminal not less than 2 feet 600 millimeter high will be regarded as sufficient. When the structure does not end in a peak, air terminals not less than 2 feet 600 millimeter high shall be provided at intervals not exceeding 25 feet 7600 millimeter along the perimeter of the structure. When the tank or tower is an adjunct of a building, near or touching the perimeter, one of the down conductors shall be extended directly to a ground connection and the other shall be

connected to the lightning protection system of the building. When tank or tower is set well within the perimeter of a building, both down conductors shall be connected to the lightning protection system of the building. When the height of the structure exceeds 100 feet 30 meter the down conductors shall be cross-connected midway between the top and bottom. Where buried metal pipes enter the tank or tower, one down connector shall be connected to the pipes, approximately 1 foot 300 millimeter below grade. Metal guy wires or cables set in concrete or attached to buildings or nonconducting supports shall be grounded to a ground rod driven full length into the ground.

3.7.2 [Metal] [Reinforced Concrete]

[Metal] [Reinforced concrete] tanks and towers shall be made electrically continuous. Electrical continuity may be provided by [bolting] [riveting] [exothermically welding] metal and tying or clipping reinforcing bars, unless otherwise noted. Air terminals and down conductors shall be required except on bolted, riveted, or welded 3/16-inch 5 millimeter minimum, steel plate tanks. Ground connections and grounding electrodes are not required on metal tanks that are electrically continuous with a metallic underground pipe system. On other structures, two ground connections shall be provided approximately 180 degrees apart, at the base of the structure. Where buried metal pipes enter the tank or tower, one ground connection shall be connected to them, approximately 1 foot 300 millimeter below finished grade. Metal guy wires on tanks and towers shall be grounded. Metal guy wires or cables attached to steel anchor rods set in earth will be considered as grounded. Metal guy wires or cables set in concrete or attached to buildings or nonconducting supports shall be grounded to a ground rod driven full length into the ground.

3.8 STACKS

Metal guy wires for stacks shall be grounded. Metal guy wires or cables attached to steel anchor rods set in the earth will be considered as sufficiently well grounded.

Metal guy wires or cables attached to anchor rods set in concrete or attached to buildings or nonconducting supports shall be grounded to a ground rod driven full length into the ground.

3.8.1 Metal Stacks

Metal smokestacks shall be electrically continuous and be grounded. Where the construction of the foundation is not such as to provide [_____] ohms maximum to ground, the stack shall be grounded to two ground rods driven full length into the earth. Ground rods shall be located approximately 180 degrees apart and shall be set not less than 3 feet 900 millimeter not more than 8 feet 2400 millimeter from the nearest point of the stack foundation.

3.8.2 Nonmetallic Stacks

On nonmetallic smokestacks constructed of [brick] [hollow tile] [concrete], the air terminals shall be made of [solid copper] [copper alloy] [stainless steel] [Monel metal]. They shall be uniformly distributed about the rim of the stack at intervals not exceeding 8 feet 2400 millimeter and shall extend at least 30 inches 750 millimeter above the rim of the stack.

Air terminals shall be electrically connected together by means of a metal band or ring to form a closed loop about 2 feet 600 millimeter below the

top of the stack.

Where the stack has a metal crown, the air terminals shall be connected thereto. Where stacks have a metal lining extending part way up, the lining shall be connected to the air terminal at its upper end and grounded at the bottom. At least two down conductors shall be provided on opposite sides of the stack leading from the ring or crown at the top to the ground. When the stack is an adjunct of a building near or touching the building perimeter, one of the down conductors shall be extended directly to a ground connection while the other may be connected to a lightning protection system on the building. On stacks exceeding 160 feet 50 meter in height, the down conductors shall be cross-connected approximately midway between the top and the bottom. Joints in conductors shall be as few as practicable and of such construction as to provide a strength in tension equal to that of the conductor.

Fasteners of [copper] [copper-bronze alloy] shall be spaced not over 3 feet 900 millimeter apart for vertical conductors and not over 2 feet 600 millimeter apart for horizontal conductors. To prevent corrosion by gases, copper air terminals, conductors, and fasteners within 25 feet 7600 millimeter of the top of the stack shall have a continuous covering of lead at least 1/16 inch 1.5 millimeter thick. Stacks partly or wholly of reinforced concrete shall conform to the requirements for nonmetallic stacks, and in addition, the reinforcing steel shall be electrically connected to down conductors at the top and bottom of the concrete.

3.9 RAILROADS

Rails that are not electrically continuous and rail switches shall be bonded together by means of flexible copper cable or straps for a distance of at least 100 feet 30 meter on each side of structures in which explosives, ammunition, or explosive ingredients are stored, handled, manufactured, or processed. These rails shall also be grounded. Rails shall be grounded at points 150 feet 45 meter on each side of overhead line crossings in excess of 600 volts and rails shall be bonded between grounds. At points where the tracks come within 25 feet 7600 millimeter of structures provided with a grounding system, such grounds shall be interconnected to the nearest rail. Cables used for the interconnection shall be [at least 3/4-inch 20 millimeter diameter] [the same size as the conductors used on the structure]. Isolation joints shall be installed in metal rails outside of hazardous areas to avoid stray currents being conducted in to the bonded or grounded area.

3.10 PIERS AND WHARVES

Lightning protection systems for piers and wharves shall conform to the applicable requirements contained in this section for the type of construction indicated.

3.11 INTERCONNECTION OF METAL BODIES

Metal bodies of conductance shall be protected if not within the zone of protection of an air terminal. All metal bodies of conductance having an area of 400 square inches 0.258 square meter or greater or a volume of 1000 cubic inches 0.016 cubic meter or greater shall be bonded to the lightning protection system using main size conductors and a bonding plate having a surface contact area of not less than 3 square inches 1900 square millimeter. Metal bodies of inductance shall be bonded at their closest point to the lightning protection system using secondary bonding conductors and

fittings. A metal body that exceeds 5 feet 1500 millimeter in any dimension, that is situated wholly within a building, and that does not at any point come within 6 feet 1800 millimeter of a lightning conductor or metal connected thereto shall be independently grounded.

3.12 FENCES

Metal fences that are electrically continuous with metal posts extending at least 2 feet 600 millimeter into the ground require no additional grounding. Other fences shall be grounded on each side of every gate. Fences shall be grounded by means of ground rods every 1000 to 1500 feet 300 to 450 meter of length when fences are located in isolated places, and every 500 to 750 feet 150 to 230 meter when in proximity 100 feet 30 meter or less to public roads, highways, and buildings. [Where the fence consists of wooden posts and horizontal metal strands only, down conductors consisting of AWG No. 8 13 millimeter copper wire or equivalent shall be run from the ground rod the full height of the fence and fastened to each wire, so as to be electrically continuous.] Connection to ground shall be made from the post where it is of metal and is electrically continuous with the fencing. All metal fences shall be grounded at or near points crossed by overhead lines in excess of 600 volts and at distances not exceeding 150 feet 45 meter on each side of line crossings.

Fences shall be grounded at corner posts, end posts, and gate posts, using removable ground clamps on the fence posts and split-bolt connectors suitable for dissimilar metals on the fence fabric and barbed wire. Gates shall be bonded to the adjacent fence post utilizing flexible copper grounding braid with sufficient slack to permit 180-degree opening of the gate. Flexible copper ground braid shall have an ampacity equivalent to that of the fence ground wire.

Grounding connections shall be exothermic-fusion-welded, except where bolted connections are indicated on the contract drawings.

3.13 EXTERIOR OVERHEAD PIPE LINES

Overhead pipes, conduits, and cable tray that enter a building containing explosives shall be properly grounded on the exterior of the building, preferably to the building grounds at points where the pipes enter the building. Where a separate ground is used, the pipes shall also be bonded to the building ground at points where the pipes are closest to the ground connections. In addition, the pipes shall be bonded to any metallic masses that are within 6 feet 1800 millimeter of the pipes.

3.14 SEPARATELY MOUNTED SHIELDING SYSTEM

3.14.1 Mast Type

Mast-type protection shall consist of a pole, which, when of a nonconducting material, shall be provided with an air terminal mounted to the top, extending not less than 2 feet 600 millimeter nor more than 5 feet 1500 millimeter above the top pole and a down conductor run down the side of the pole. Where resistance of the metal pole to ground is [_____] ohms or less, additional grounding is unnecessary. Where resistance exceeds [_____] ohms or less, additional grounding shall be provided, and the ground connection shall be fastened to the metal pole and the ground. When a ground rod is necessary, the rod shall be driven approximately 6 feet 1800 millimeter from the base of the pole. When resistance to ground of this rod is more than [_____] ohms, an additional ground rod shall be

driven not closer than 10 feet 3000 millimeter to the first rod. When resistance of the system to ground is still greater than [_____] ohms when the two ground rods are connected together, a counterpoise, consisting of approximately 30 feet 9000 millimeter of No. AWG 1/0 25 millimeter copper cable buried in a trench not less than 2 feet 600 millimeter deep in the form of a circle or square around the base of the pole, shall be provided. When a counterpoise is used, the entire system resistance requirement of [_____] ohms or less need not be met. Grounding system at the base of the pole shall be interconnected with any grounding system provided for the protected structure.

3.14.2 Overhead Ground-Wire Type

Overhead ground-wire type of protection shall consist of two or more poles electrically connected to each other by overhead conductors. Where the poles are made of a nonconducting material an air terminal shall be mounted to the top of each pole and shall extend not less than 2 feet 600 millimeter nor more than 5 feet 1500 millimeter above the top of the pole. Down conductors shall be run down the side of the pole, or a guy wire may be used as a conductor. When the guy wire is used, the guy wire and the overhead ground wire shall be dead-ended at the pole. Overhead ground wires and the guy wires shall then be connected to each other by a separate cable using standard cable clamps in such manner that the discharge will not be reversed at any point. Guy wires used as down conductors shall be grounded by means of separate ground rods with cable connections clamped to the lower end of guy wire. Resistance to ground shall not exceed [_____] ohms. Where metal poles are used, air terminals are not required and if resistance of the poles to ground is [_____] ohms or less, additional grounding is unnecessary. Where the resistance to ground exceeds [_____] ohms, additional grounding shall be provided and the ground connection shall be fastened to the metal pole and the ground. Height of the poles shall be sufficient to provide a clearance of not less than 6 feet 1800 millimeter from the base of each pole. When the resistance to ground of this rod is more than [_____] ohms, an additional ground rod shall be driven not closer than 10 feet 3000 millimeter from the first rod. When the resistance of the entire system to ground is still greater than [_____] ohms, a counterpoise consisting of at least 50 feet 15 meter of AWG No. 1/0 copper cable buried in a trench not less than 2 feet 600 millimeter deep shall be provided. When a counterpoise is used, the entire system resistance requirement of [_____] ohms or less need not be met.

3.15 SYSTEM RATINGS

Certificates shall be submitted showing compliance with UL requirements for "Master Label" ratings.

Lightning-protection systems conforming to the installation requirements of UL 96A shall be qualified for a UL "Master Label" rating. Installed lightning-protection system shall be inspected and approved by a certified UL inspector.

-- End of Section --